3.183 The pump in Fig. P3.183 draws gasoline at 20°C from a reservoir. Pumps are in big trouble if the liquid vaporizes (cavitates) before it enters the pump. (a) Neglecting losses and assuming a flow rate of 65 gal/min, find the limitations on (x, y, z) for avoiding cavitation. (b) If pipe-friction losses are included, what additional limitations might be important?

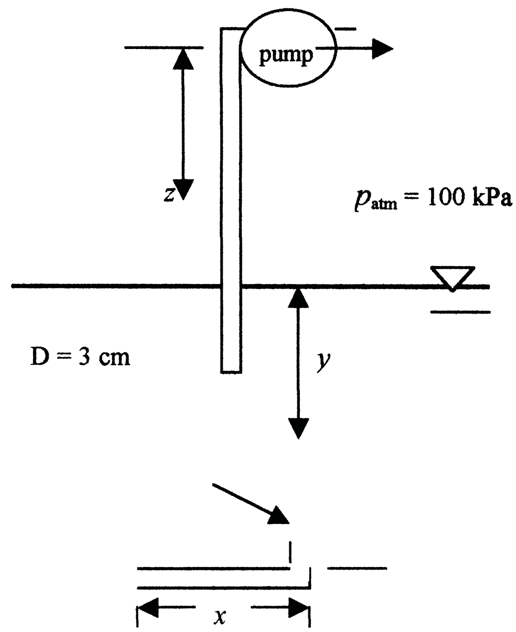

Fig. P3.183

Solution: (a) From Table A.3, $\rho = 680$ kg/m^3 and $p_v = 5.51E{+}4$.

$$z_2 - z_1 = y + z = \frac{p_1 - p_2}{\rho g} = \frac{(p_a + \rho g y) - p_v}{\rho g}$$

$$y + z = \frac{(100{,}000 - 55{,}100)}{(680)(9.81)} + y \quad z = 6.73\ m$$

Thus make length z appreciably less than 6.73 (25% less), or **z < 5 m**. *Ans*. (a)

(b) **Total pipe length ($x + y + z$) restricted by friction losses**. *Ans*. (b)

3.184 For the system of Prob. 3.183, let the pump exhaust gasoline at 65 gal/min to the atmosphere through a 3-cm-diameter opening, with no cavitation, when x = 3 m, y = 2.5 m, and z = 2 m. If the friction head loss is $h_{loss} \approx 3.7(V^2/2g)$, where V is the average velocity in the pipe, estimate the horsepower required to be delivered by the pump.

Solution: Since power is a function of h_p, Bernoulli is required. Thus calculate the velocity,

$$V = \frac{Q}{A} = \frac{(65\text{ gal/min})\left(6.3083E{-}5\,\frac{\text{m}^3/\text{s}}{\text{gal/min}}\right)}{\frac{\pi}{4}(0.03^2)} = 5.8\text{ m/s}$$

The pump head may then be found,

$$\frac{p_1}{\gamma} + z_1 = \frac{p_2}{\gamma} + z_2 + h_f - h_p + \frac{V_j^2}{2g}$$

$$\frac{100{,}000 + (680)(9.81)(2.5)}{(680)(9.81)} - 2.5 = \frac{100{,}000}{(680)(9.81)} + 2 + \frac{3.7(5.8^2)}{2(9.81)} - h_p + \frac{(5.8^2)}{2(9.81)}$$

$$h_p = 10.05\ m$$

$$P = \gamma Q h_p = (680)(9.81)(0.0041)(10.05) \quad \mathbf{P = 275\ W = 0.37\ hp} \quad \mathit{Ans.}$$

3.185 Water at 20°C flows through a vertical tapered pipe at 163 m^3/h. The entrance diameter is 12 cm, and the pipe diameter reduces by 3 mm for every 2 meter rise in elevation. For frictionless flow, if the entrance pressure is 400 kPa, at what elevation will the fluid pressure be 100 kPa?

Solution: Bernouilli's relation applies,

$$\frac{p_1}{\gamma} + z_1 + \frac{Q_1^2}{2gA_1^2} = \frac{p_2}{\gamma} + z_2 + \frac{Q_2^2}{2gA_2^2} \qquad (1)$$

Where,

$$\mathrm{d_2 = d_1 - 0.0015(z_2 - z_1)} \qquad (2)$$

Also, $Q_1 = Q_2 = Q$ = (163 m^3/h)(h/3600s) = 0.0453 m^3/s; γ = 9790; z_1 = 0.0; p_1 = 400,000; and p_2 = 100,000. Using EES software to solve equations (1) and (2) simultaneously, the final height is found to be ***z* ≈ 27.2 m**. The pipe diameter at this elevation is d_2 = 0.079 m = 7.9 cm.
